Use of the Short Physical Performance Battery Score to Predict Loss of Ability to Walk 400 Meters: Analysis From the InCHIANTI Study

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Background. Early detection of mobility limitations remains an important goal for preventing mobility disability. The purpose of this study was to examine the association between the Short Physical Performance Battery (SPPB) and the loss of ability to walk 400 m, an objectively assessed mobility outcome increasingly used in clinical trials.

Methods. The study sample consisted of 542 adults from the InCHIANTI ("Invecchiare in Chianti," aging in Chianti area) study aged 65 and older, who completed the 400 m walk at baseline and had evaluations on the SPPB and 400 m walk at baseline and 3-year follow-up. Multiple logistic regression models were used to determine whether SPPB scores predict the loss of ability to walk 400 m at follow-up among persons able to walk 400 m at baseline.

Results. The 3-year incidence of failing the 400 m walk was 15.5%. After adjusting for age, sex, education, body mass index, Mini-Mental State Examination, number of medical conditions, and 400 m walk gait speed at baseline, SPPB score was significantly associated with loss of ability to walk 400 m after 3 years. Participants with SPPB scores of 10 or lower at baseline had significantly higher odds of mobility disability at follow-up (odds ratio [OR] = 3.38, 95% confidence interval [CI]: 1.32–8.65) compared with those who scored 12, with a graded response across the range of SPPB scores (OR = 26.93, 95% CI: 7.51–96.50; OR = 7.67, 95% CI: 2.26–26.04; OR = 8.28, 95% CI: 3.32–20.67 for SPPB ≤ 7, SPPB 8, and SPPB 9, respectively).

Conclusions. The SPPB strongly predicts loss of ability to walk 400 m. Thus, using the SPPB to identify older persons at high risk of lower body functional limitations seems a valid means of recognizing individuals who would benefit most from preventive interventions.

Key Words: Mobility—400 m walk—Incidence of disability—Functional limitation—Aging.

MOBILITY, defined as the ability to move independently from one location to another, is essential to independence and is a key component of overall quality of life. Among older persons, the ability to walk remains a critical element of most basic and instrumental activities of daily life (1), and early decrements in mobility function are prognostic of future adverse health events. An accurate and objective assessment of physical function, as it relates to risk or prognosis of mobility disability, is a desired entity for both clinicians and researchers alike.

Performance-based measures of physical function have been strongly associated with health services utilization, hospitalization, institutionalization, falls, and mortality (2–12). Even among nondisabled individuals, performance measures have been shown to predict the onset of self-reported disability and capture a wide range of function (13,14). However, whether performance-based measures of physical function predict objectively measured events of mobility loss has received less attention. Objective performance-based measures of mobility loss provide a more valid assessment than self-report measures, especially for older adults who either do not

walk long distances in their daily lives or have an inaccurate perception of how much they walk (15). Identifying valid and reliable measures of mobility disability is particularly important to improve randomized clinical trials in older adults (16).

Previous studies have shown that the Short Physical Performance Battery (SPPB) is a powerful predictor of disability, institutionalization, and mortality (17,18), which is increasingly used in randomized controlled trials in older adults. The SPPB score and time to walk 400 m have been shown to be highly correlated (19), but the ability of the SPPB to predict loss of ability to complete a 400 m walk test has only been demonstrated in a small, highly selected sample (20). In this pilot study, Chang and colleagues (20) provide estimates of the incidence of loss of mobility, which, due to the small and selective sample, may be an unreliable estimate of incident loss of 400 m walk ability. Hence, our current study addresses the need for a larger study sample of incident mobility disability, as indicated by the loss of ability to complete the 400 m walk, and how it relates to lower extremity functioning as measured by the SPPB. Providing

additional data and information from a larger, less functionally limited sample, according to incidence rates for mobility disability and SPPB score, will be useful for screening in clinical trials that target an at-risk population. For instance, the Lifestyle Interventions and Independence for Elders Pilot (LIFE-P) Study selected persons with SPPB scores at or below 9 and assumed that these individuals were at risk for failing the 400 m walk (21). This assumption has not been evaluated in a community-based population.

Given that some older adults may overreport their ability to walk 400 m (20) and the need to detect older adults at risk of mobility disability, the purpose of the current study was to assess whether the SPPB predicts inability to complete the 400 m walk test at 3-year follow-up among a sample of community-dwelling older persons able to complete the walk at baseline.

METHODS

Study Population

The InCHIANTI ("Invecchiare in Chianti," aging in Chianti area) study is a longitudinal epidemiological study focusing on factors that contribute to the decline in mobility during later life. The study was designed by the Laboratory of Clinical Epidemiology of the Italian National Research Council of Aging (Florence, Italy) in conjunction with the Laboratory of Epidemiology, Demography, and Biometry at the National Institute on Aging (Bethesda, MD). Using a multistage stratified sampling method, participants were randomly selected from community-dwelling residents of Greve and Bagno a Ripoli, both towns located in Chianti, Italy. The InCHIANTI study methodology and design have been previously published (22).

There were 1,026 participants aged 65 and older who underwent medical and physical function evaluations. Among these people, 801 were able to complete the 400 m walk at baseline. By 3-year follow-up, 35 of the participants died prior to follow-up assessment and an additional 156 were no longer participating in the study. Of the 801 people who completed the 400 m walk at baseline, 542 people were included and 259 were excluded from these analyses because they did not have data on the 400 m walk at follow-up (see *Measures*).

Measures

The scoring of the SPPB was initially developed using data from the Established Populations for the Epidemiologic Studies of the Elderly (17). The test consists of three components: balance, timed 4 m walk, and chair stands. The standing balance portion required participants to maintain a side-by-side, semitandem, and tandem stance for 10 seconds, with scores ranging from 0 to 4 (maximum score). The fastest time of two 4 m usual-pace walk attempts was used. The chair stands required participants to rise from a chair with arms across their chest for five repetitions. Cate-

gorical scores (range 0–4) for the 4 m walk and chair stands were based on timed quartiles previously established in a large population (17,23). Individuals unable to complete either task received a score of 0. The sum of the three components comprised the final SPPB score with a possible range from 0 to 12 (12 indicating the highest degree of lower extremity functioning). Full criteria for test administration are available at www.grc.nia.nih.gov/branches/ledb/sppb/index.htm (24).

The objective performance-based test used to assess mobility disability was inability to complete the 400 m walk. Participants were asked to walk 20 laps on a 20 m course as fast as possible at a steady pace. Time per lap completion was collected using a photo-based chronometer and overall gait speed was calculated. A maximum of two standing rests were allowed for 2-minute intervals each. Participants were classified as unable to complete the walk at follow-up if they attempted but failed the 400 m walk, had self-reported difficulty walking 8 m without help, had difficulty keeping their balance with feet together for 10 seconds—part of the Frailty and Injuries: Cooperative Studies of Intervention Techniques (25) battery, had severe dyspnea and dyspnea at rest in the past 3 months, had angina or chest pain with intense dyspnea, or were not tested but had evidence of inability to complete the walk (as indicated by inability to complete a 4 m walk or a 4 m walk gait speed of <0.6 m/s at usual pace) (26). No maximum time limits were used as an indicator of the inability to complete the 400 m walk.

There were 268 individuals excluded from the 400 m walk test. An a priori list of safety criteria was used to identify whether a participant could safely attempt to walk 400 m. Individuals were excluded from the test at follow-up if they refused to participate; had severe pathological changes on the electrocardiogram; severe pain in the back, hip, or knee; had a heart rate of less than 40 beats/min or more than 125 beats/min; systolic blood pressure of greater than 180 mm Hg; diastolic blood pressure of greater than 100 mm Hg; cognitive impairment; or any of the following conditions in the past 3 months: myocardial infarction, heart surgery, angina or chest pain, or loss of consciousness. Compared with the 542 participants included in the analyses, the 259 excluded individuals were not statistically different in body mass index (BMI) ($p = .26$), education ($p = .50$), gender ($p = .54$), and SPPB ($p = .28$). However, the 259 excluded individuals were significantly older ($p < .01$), more cognitively impaired ($p = .05$), had a slower baseline 400 m walk gait speed ($p < .01$), and had a greater number of chronic conditions ($p = .02$) compared with the 542 participants included in the analyses.

Other covariates used in data analysis included participant's age, sex, and years of education. The total number of medical conditions was calculated based on the presence of cancer, hypertension, angina, myocardial infarction, congestive heart failure, stroke, Parkinson's disease,
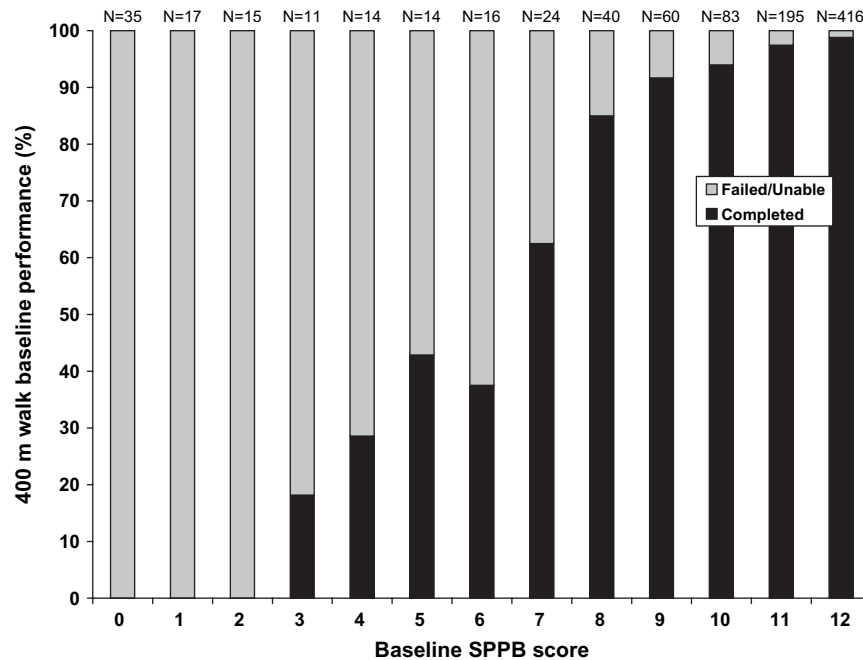
Figure 1. Four hundred–meter walk baseline completion by short physical performance battery score.

diabetes mellitus, chronic obstructive pulmonary disease, peripheral arterial disease, hip fracture, and arthritis in the hip or knee. All participants were examined by a trained geriatrician, and diseases were ascertained according to standard, preestablished criteria and algorithms based on those used in the Women's Health and Aging Study (27). A summary variable was created for the presence of zero, one, two, and three or more chronic conditions. Also included in the analyses were BMI (calculated as weight in kilograms divided by height in meters squared) and the Mini-Mental State Examination (MMSE), used to assess cognitive functioning (28).

Statistical Analyses

All analyses (with the exception of that in Figure 1) were adjusted for age and sex.

Logistic regression was used to determine whether SPPB scores predicted the inability to walk 400 m 3 years after baseline. Based on the distribution of SPPB scores, separate dummy variables were created to identify participants with scores of 7 or less, 8, 9, 10, and 11, with 12 as the reference value. Three models were determined, all adjusted for age and sex (Table 2). Model I included indicator (dummy) variables for SPPB scores. In model II, the following covariates were added: education, BMI, MMSE, and total number of medical conditions. Finally, in model III, 400 m walk gait speed at baseline was added as a continuous variable (m/s). Analyses were performed using SAS 9.1 (SAS Institute, Inc, Cary, NC) and STATA 9.0 (Stata Corp, College Station, TX).

RESULTS

Figure 1 shows the percentage of participants who failed and completed the 400 m walk at baseline according to SPPB score. The percentage of individuals completing the 400 m walk at baseline increased with higher SPPB scores. Among people with SPPB scores of 0–2, no participants completed the 400 m walk at baseline. For scores of 3–12, there was a generally graded increase in the proportion completing the 400 m walk. Of the individuals with SPPB scores of 7 or less, 20%–60% of them completed the 400 m walk. In those with SPPB scores of 8 or higher, more than 80% completed the 400 m walk at baseline.

Among the 542 participants who completed the walk at baseline and survived to 3-year follow-up, 84 (15.5%) were unable to complete the walk at 3-year follow-up. Participants unable to complete the 400 m walk at follow-up were significantly older, less educated, more cognitively impaired, and had a greater number of medical conditions at baseline compared with those able to complete the walk (Table 1). Figure 2 shows the age-sex–adjusted incidence of the inability to complete the 400 m walk at follow-up by baseline SPPB score, with 95% confidence interval bars. Loss of ability to walk 400 m was greatest (66%) among participants with baseline SPPB scores of 7 or less. Among participants with baseline SPPB scores of 8–10, 21%–36% were unable to complete the 400 m walk, whereas 6% of individuals with SPPB scores of 11 and 5.8% of individuals with SPPB scores of 12 were unable to complete the walk 3 years later.

After adjusting for age and sex, individuals with SPPB scores of 10 or less had a significantly higher risk of

Table 1. Study Sample Characteristics by 400 m Walk Follow-Up: InCHIANTI Study (N = 542)

	Completed	Failed/Unable	p
n	458	84	
Age (y, mean ± SD)	71.6 ± 5.1	77.7 ± 6.9	<.01
Women (%)	51.5	72.6	<.01
Years of education (mean ± SD)	5.9 ± 3.3	4.6 ± 3.1	<.01
Mini-Mental State Examination score (mean ± SD)	26.0 ± 3.0	23.9 ± 4.5	<.01
Number of medical conditions (%)			
0	29.9	17.9	<.01
1	45.4	32.1	
2	19.7	29.8	
3+	5.0	20.2	
Body mass index (mean ± SD)	27.2 ± 3.6	27.4 ± 4.4	.71

Note: SD = standard deviation; number of medical conditions = sum of cancer, hypertension, angina, myocardial infarction, congestive heart failure, stroke, Parkinson's disease, diabetes mellitus, chronic obstructive pulmonary disease, peripheral arterial disease, arthritis (hip or knee).

Figure 2. Age-sex–adjusted proportion of participants unable to complete the 400 m walk at follow-up by baseline short physical performance battery score, with 95% confidence interval bars.

developing mobility disability compared with individuals with a score of 12 (Table 2, model I). Participants with SPPB scores of 7 or less were 32 times as likely to have incident mobility disability compared to participants with SPPB scores of 12; participants with a score of 10 were 4.2 times more likely to develop mobility disability than the reference group, whereas those with a score of 11 had a lower increased risk (odds ratio [OR] = 1.43, p = .40, model I). The addition of BMI, MMSE, years of education, and number of medical conditions in model II did not substantially change the magnitude or significance of the SPPB's ability to predict inability to walk 400 m. After further adjusting for gait speed, the SPPB as a continuous variable remained a significant predictor of the inability to walk 400 m (model III). For each unit increase in SPPB score, the odds of incident disability decreased by approximately 25%. Additionally, having three or more chronic conditions (OR = 3.14, p = .03, model II) and 400 m walk gait speed (OR per 0.1 m/s difference = 0.62, p < .01, model III) were significant predictors of inability to complete the 400 m walk at follow-up. Finally, when analyses were stratified by sex and adjusted for age, the association of SPPB scores with failing the 400 m walk test was essentially the same in men and in women. Furthermore, there were no statistically significant interactions between the SPPB and age or sex (p = .44 and .26, respectively).

Table 3 shows the predictive values for a given SPPB cut point with relation to the loss of ability to walk 400 m. With an SPPB score of 9 or less, the positive predictive value (PPV) is 56%, negative predictive value (NPV) 92%, sensitivity 54%, specificity 92%, positive likelihood ratio 7.01, and the negative likelihood ratio 0.50. Compared with using an SPPB score of 9 or less as a cut point, an SPPB score of 10 or less yields a lower PPV (45%), higher NPV (94%), higher sensitivity (69%), lower specificity (84%), and lower positive and negative likelihood ratios (4.45 and 0.37, respectively).
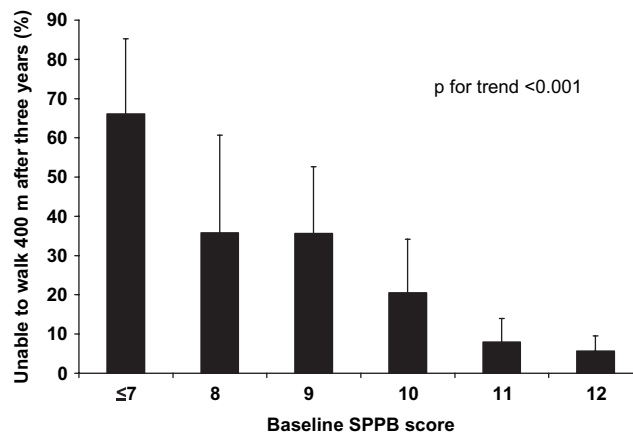
DISCUSSION

This study finds that the SPPB strongly predicts loss of ability to walk 400 m for a period of 3 years. Older Italian adults with low SPPB scores (10 or less) had significantly higher odds of losing the ability to walk 400 m, an objective measure of mobility disability 3 years later, with a graded response across the range of SPPB scores (scores of 3–12). The association of the SPPB was robust to adjustments for comorbidities and cognitive impairment that contribute to mobility decline in older adulthood. Even controlling for endurance-based 400 m gait speed at baseline, the SPPB remained a significant predictor of mobility disability. Ultimately, these findings provide further evidence that the SPPB is a powerful measure of lower extremity function in old age, and it reflects the notion that the SPPB is a powerful tool for screening older individuals and identifying those at risk of disability.

The time to complete the 400 m walk has been associated with adverse health outcomes, including a higher risk of incident cardiovascular disease, mortality, and mobility disability (defined as two consecutive reports of severe difficulty of inability to walk ¼ mile or climb stairs) in the Health, Aging, and Body Composition (HABC) Study (29). In contrast to our study, which used the SPPB to predict inability to complete the 400 m walk, the HABC Study used the 400 m walk time as a predictor of a subsequent self-reported mobility disability outcome.

Prior studies of physical function have relied on self-reported ability to walk 400 m. However, misclassification might occur when individuals do not regularly walk that distance and speculate on their abilities or when individuals cannot accurately gauge distance. A more accurate and reliable assessment is to actually have the participant attempt to walk 400 m under direct observation. In real-world applications, the ability to walk 300–400 m serves as a basic indicator of physical functioning. Among older adults, the ability to walk 400 m serves as an appropriate proxy for mobility within the community (30).

Table 2. Logistic Regression Models Predicting Inability to Complete 400 m Walk at Follow-Up Among
Those Able to Walk 400 m at Baseline (N = 542)

Baseline Variables	Model I		Model II		Model III	
	Odds Ratio (95% CI)	p	Odds Ratio (95% CI)	p	Odds Ratio (95% CI)	p
Age (y)	1.11 (1.06–1.17)	<.01	1.10 (1.05–1.16)	<.01	1.05 (1.00–1.11)	.06
Women (vs men)	1.47 (0.78–2.74)	.23	1.42 (0.73–2.79)	.30	0.98 (0.49–1.98)	.96
SPPB score (vs 12)						
≤7	32.14 (9.57–107.92)	<.01	26.93 (7.51–96.50)	<.01		
8	9.16 (2.87–29.22)	<.01	7.67 (2.26–26.04)	<.01		
9	9.11 (3.74–22.17)	<.01	8.28 (3.32–20.67)	<.01		
10	4.23 (1.73–10.35)	<.01	3.38 (1.32–8.65)	.01		
11	1.43 (0.62–3.29)	.40	1.40 (0.60–3.28)	.44		
12	1.00		1.00			
SPPB score (continuous)					0.76 (0.61–0.94)	.01
Education			0.98 (0.88–1.09)	.72	1.00 (0.90–1.12)	.95
BMI			1.02 (0.94–1.10)	.66	0.99 (0.92–1.07)	.87
Mini-Mental State Examination score			0.90 (0.82–1.00)	.05	0.92 (0.83–1.02)	.12
Number of medical conditions (vs 0)						
1			0.71 (0.32–1.59)	.40	0.59 (0.26–1.34)	.21
2			1.65 (0.72–3.81)	.24	1.12 (0.47–2.67)	.79
3+			3.14 (1.14–8.63)	.03	2.03 (0.72–5.73)	.18
400 m walk gait speed (per 0.1 m/s difference) (continuous)					0.62 (0.50–0.77)	<.01

Note: SPPB = Short Physical Performance Battery (0–12); BMI = body mass index; CI = confidence interval; number of medical conditions = sum of cancer, hypertension, angina, myocardial infarction, congestive heart failure, stroke, hip fracture, Parkinson's disease, peripheral arterial disease, diabetes mellitus, chronic obstructive pulmonary disease, arthritis (hip or knee).

The theoretical pathway from disease to disability outlines the functional domains that can be assessed along this pathway (31–33). Such models view the disablement process as a sequence of steps in which disease leads to impairments (dysfunctions or structural abnormalities in body systems), which lead to functional limitations (limited ability to perform basic cognitive and physical tasks), which in turn lead to disability (further restriction or inability to perform social roles or desired activity within a given environment). With this in mind, physical performance measures, such as the SPPB, were developed to assess functional limitations.

The association of the SPPB with loss of ability to complete the 400 m walk has previously been shown in a very small, highly selected sample of persons with SPPB scores ranging from 4 to 9 at baseline (20). By completing a similar study using a larger community-based sample of older adults with a wider age range and a wider range of functioning that was followed (N = 542) for a longer follow-up period (3 years as opposed to 21 months in the Chang and

colleagues' article), our study helps close a gap in the current literature. Our study design provides rates of incident mobility disability in a larger, less functionally limited sample and shows the ability of the SPPB to predict incident mobility disability across a wider range of functioning (SPPB scores up to 12).

By further investigating this association in a larger community-based sample and estimating the 3-year incidence of inability to walk 400 m (15.5%), we expected similar results compared with those of Chang and colleagues (i.e., showing that lower SPPB scores predicted incident mobility disability) (20). We were, however, surprised to discover how strongly the SPPB predicted loss of ability to walk 400 m, particularly after adjusting for multiple covariates. For example, individuals with an SPPB score of 10, a fairly high level of performance, were 3.4 times as likely to become mobility disabled as those scoring a 12 (Table 2). Additionally, having an SPPB score of 10 or less was associated with a PPV of 45%, compared with a PPV of 56% for having an SPPB score of 9 or less (Table 3). With a graded

Table 3. Screening Test Performance Values for a Given SPPB Cut Point (N = 542)

SPPB Cut Point (less than or equal to)	PPV	NPV	Sensitivity	Specificity	Positive Likelihood Ratio	Negative Likelihood Ratio
7	0.75	0.87	0.18	0.99	16.36	0.83
8	0.64	0.88	0.30	0.97	9.74	0.72
9	0.56	0.92	0.54	0.92	7.01	0.50
10	0.45	0.94	0.69	0.84	4.45	0.37
11	0.27	0.95	0.83	0.59	2.03	0.28

Note: SPPB = Short Physical Performance Battery; PPV = positive predictive value; NPV = negative predictive value.

risk across the entire spectrum of SPPB scores, setting a cut point for the SPPB depends on how the researcher or clinician intends to apply the battery (eg, a more sensitive cut point may be ideal for a given situation, whereas a cut point with higher specificity is optimal for another situation). Overall, this study indicates that using an SPPB cut point of 10 or less is acceptable, given that our results (from Table 2) indicate that these individuals are at a significantly increased risk of mobility disability.

Despite the many strengths of our study, it also had some limitations. Due to the exclusion criteria based on participant's ability to safely attempt the 400 m walk, the participant pool was substantially reduced. Thus, our results are potentially biased and probably indicate a conservative estimation of incident mobility disability.

Approximately 40% of individuals aged 70 and older are nondisabled in activities of daily living and mobility, while simultaneously exhibiting SPPB scores indicative of moderate or high risk of future disability (34). The SPPB, as indicated in the current study, provides a "vital sign" of physical function (35). For instance, the SPPB enables one to monitor and quantify functional limitations prior to disabilities. In doing so, the SPPB is a useful assessment tool for early detection of older adults at risk of developing disability and affords an opportunity for preventive interventions in high-risk persons prior to the onset of disability (18).

General physical activity and more specific interventions, such as Tae Kwon Do and intense Tai Chi, have been linked to improvements in physical performance among older adults (36–44). The LIFE-P Study, a randomized control trial that includes a physical activity intervention, selected participants with SPPB scores of 9 or less and found that the physical activity intervention improved physical function in this vulnerable population. Authors of the LIFE report suggest that physical activity linked to improvements on the SPPB would likely improve later health outcomes, including mobility disability (21). Hence, using the SPPB to recognize individuals who would benefit most from preventive intervention brings us one step closer towards increasing years of healthy, disability-free life.

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